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Mathematics in Colleges and Universities: A Survey

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THE RAPID growth of science and technology in recent years has underscored the importance of mathematics to our national welfare and security. With the aid of mathematics we are, at one end of the scale, probing the intricacies of the atom and, at the other end, reaching for the moon and planets. To an extent, the state of development of mathematics in a nation is a measure of its scientific and technological strength.

Mathematics has traditionally played a major role in the progress of the physical sciences and engineering. More recently, the increasing value of mathematics in the study of the biological sciences, the social sciences, and business has been recognized. For example, the 1960 *Annual Review of Physiology* reported:

In 1929, of 76 papers selected at random from the *American Journal of Physiology*, only 10.4 percent used mathematical equations of any sort, the most complex of which had four variables. In 1959, of 91 similar papers, 17.6 percent used equations, two with six and one with thirteen variables. Similar trends are to be seen everywhere in the literature.

Undoubtedly similar statistics can be obtained for other fields.

Vital as mathematics is as a tool in applications to other fields, it is still a worthwhile discipline in its own right. Indeed, many study mathematics because of its beauty and elegance without any thought of applications, though these may appear later as significant by-products. Mathematics is actually one of the liveliest research fields at the present time. In addition, the mathematically based fields of statistics and computing are developing tremendously. For the

computing field alone, an official of the Association for Computing Machinery estimates that approximately 300,000 programmers will be needed in the next eight to ten years.

Number of degrees in mathematics

In recent years the number of bachelor's degrees in mathematics has been growing more rapidly than in any other major field of study. In 1954-55, a total of 4,034 degrees in mathematics (including statistics and actuarial science) was conferred by U.S. institutions. In 1959-60, the number was 11,437. Based on U.S. Office of Education junior-year major surveys, it is estimated that about 15,100 degrees were conferred in 1961-62. This would be only about 1,000 fewer than the estimated number awarded in all the physical sciences combined. In 1954-55, a total of 10,516 bachelor degrees was conferred in all the physical sciences combined, compared to the 4,034 degrees in mathematics. Thus, whereas a few years ago the number of degrees in mathematics was less than 40 percent of the number in all the physical sciences, now mathematics has almost caught up to the physical sciences.

In considering the above data, it should be understood that a double major is counted as one-half degree in each discipline. Consequently, there were actually more students who took majors in mathematics than the numbers of degrees indicate. Also, majors in curricula designed to train teachers of mathematics in secondary schools are included in mathematics, not in education.

The numbers of degrees at the master's and doctoral levels have also been in-

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creasing significantly. In 1954-55, a total of 761 master's degrees in mathematics was awarded; in 1959-60, a total of 1,765. In 1954-55, a total of 250 doctor's degrees in mathematics was conferred; in 1959-60, a total of 303. The figures for 1960-61 and 1961-62 have not been compiled and released as yet, but significant increases are expected at both the master's and doctor's levels for each of these years.

Staffing problems in mathematics

The great growth in mathematics instruction has caused staffing problems at many institutions. For example, last winter the vice-president of a large Midwestern state college wrote to the author and asked if he could help him find a full professor to head the department, two associate professors, and two assistant professors. He said that he had tried all the usual sources for securing prospective faculty members to no avail. Other examples, not as extreme as this one, could be cited.

According to *Teacher Supply and Demand in Universities, Colleges, and Junior Colleges, 1959-60 and 1960-61*, published by the National Education Association, college officials predict that during the years ahead the shortage of qualified college teachers will worsen in mathematics more than in any other field.

Interest in mathematics curricula

Because of the expansion of mathematics instruction and the increasing recognition of its value to other disciplines, much interest has developed in recent years in mathematics programs in colleges and universities. The Mathematical Association of America, a professional organization concerned primarily with college mathematics, established in 1953 a Committee on the Undergraduate Program in Mathematics (CUPM). As a basis for making recommendations for the improvement of mathematics curricula for various kinds of students, CUPM has

been interested in determining the existing status of mathematics programs. A *Catalogue Survey of College Mathematics Courses*, by Mosteller, Choi, and Sedransk of Harvard University, was published by CUPM in December 1961. This publication was based on a stratified sample of 286 of 1,721 institutions of higher education. A second curriculum study is being carried out by CUPM in cooperation with the National Opinion Research Center, University of Chicago. This is a study of the mathematics programs in one hundred colleges, with emphasis on the role of the smaller colleges.

U.S. Office of Education survey

The Office of Education survey of mathematics programs was planned by the author of this article in 1959 and 1960. Members of CUPM, along with a number of college mathematics professors, were helpful in the design of the questionnaire instrument which was titled *Survey of Mathematics Programs in Institutions Granting Bachelor and Higher Degrees*. The questionnaire, which asked for fall 1960 enrollment data, was distributed in January 1961 to the heads of mathematics departments in 1,014 colleges and universities in the fifty states, the District of Columbia, and Puerto Rico, which offer bachelor degrees in mathematics, and about seventy other institutions which have substantial programs but offer no degrees in mathematics. A total of 877 of these institutions, or about 81 percent, participated in the survey.

Not included in the survey were junior colleges, two-year off-campus centers of universities, extension and correspondence departments. Also excluded were institutions in which some mathematics is taught—schools of education and schools of business. Taking all these factors into consideration, it is estimated that the survey covered from two-thirds to three-fourths of the mathematics

taught in the United States during the fall of 1960.

As a result of the survey, data on graduate programs appeared in the December 1961 Special Issue of the *Notices of the American Mathematical Society*¹ and data on undergraduate programs appeared in *Guide to Undergraduate Programs in Mathematics*.² These two publications give data by individual institution and are useful when information is wanted with respect to a specific institution.

The machine data-processing of the undergraduate portion of the questionnaires was completed in the summer of 1962, the graduate portion having been hand-tabulated earlier. Following are highlights that have been obtained from the survey. Unless otherwise stated, the data given refer to the universe of 877 institutions in the study. Mention is made of significant deviations if they occur in any of the following breakdowns which were used in the analysis of the data: *by type*: universities, liberal arts colleges, teachers colleges, technological institutions; *by control*: public, private; *by region*: North Atlantic, Southeast, Great Lakes and Plains, West and Southwest; and *by enrollment size*: over 5,000, 1,500-5,000, 700-1,499, under 700.

Undergraduate enrollments

The 877 responding institutions reported that in the fall of 1960 a total of 380,164 students enrolled in freshman-year mathematics courses. Of these, 50,899 were reported as enrolled in what the responding institutions regarded as remedial courses, such as elementary and intermediate algebra, plane and solid geometry, and so forth. A total of 94,847 were reported enrolled in sophomore-year courses and 101,277 in junior- and senior-year courses.

¹ 190 Hope St., Providence 6, R.I.; \$0.50.

² Circular 1962; OE-56008 (Washington: Government Printing Office, 1962); \$0.25.

Among entering freshmen in all institutions in the fall of 1960, 52.1 percent were enrolled in college algebra, trigonometry, and courses of equivalent level; 24.9 percent, in courses of lower level; and 23.0 percent, in courses of higher level. In the North Atlantic region, 40.2 percent of the entering freshman students were enrolled in the higher level courses. Thirty-two, or 12.5 percent, of the institutions in this region offered no courses of a level lower than analytic geometry.

In the Southeast region, only 12.0 percent of the freshman students entered in higher-level mathematics courses. The percent of the freshmen in private institutions entering in upper-level mathematics courses was 33.1 percent, compared to 16.1 percent in the public institutions. Whereas 50.9 percent of the entering freshmen who were taking mathematics in technological institutions were enrolled in courses at the higher level, only 9.9 percent of those in teachers colleges were. On the other hand, 46.6 percent of those entering freshmen in teachers colleges who were taking mathematics were taking courses of a level lower than the level of college algebra and trigonometry.

Respondents were asked to give the enrollments in each course offered during the fall of 1960. At the freshman level, college algebra led with 21.9 percent of the enrollment, followed by analytic geometry and calculus with 13.6 percent and mathematical analysis with 12.3 percent. At the sophomore level, analytic geometry and calculus accounted for 39.0 percent and calculus, for 34.9 percent of the enrollment. At the junior and senior level, ordinary differential equations led with 14.5 percent of the enrollment, followed by advanced calculus with 12.4 percent.

Undergraduate curricula

A number of items on the questionnaire dealt with curricula in mathemat-

ics. A total of 759 institutions reported that they offered a liberal arts or general curriculum, the most common mathematics credit-hour requirement (27.2 percent of institutions) being in the range of 29-31 semester hours. Of those reporting data on this curriculum, 54.8 percent offered the B.A. degree; 20.3 percent, the B.S.; and 23.5 percent, either the B.A. or B.S. degree.

A total of 521 institutions offered a mathematics teaching curriculum. Again, the mode (27.7 percent of the institutions) of the semester credit-hour requirement in mathematics was in the 29-31 range. As to the types of degrees awarded, 32.7 percent gave the B.A.; 32.0 percent, the B.S.; 15.4 percent, the B.A. or B.S.; and 14.9 percent, the B.S. in Education.

A total of 27 institutions reported giving a statistical curriculum; 7, an actuarial science curriculum; and 36, an applied mathematics curriculum.

The responding institutions were asked to give the number of degrees awarded in each curriculum for the period July 1, 1959, to June 30, 1960. Not all institutions could give this data, even though they had such a curriculum. Nevertheless, the distribution of the 8,847 degrees that were reported is interesting: 55.3 percent were in liberal arts or general; 35.6 percent in mathematics teaching; 0.6 percent in statistics; 0.1 percent in actuarial science; 3.8 percent in applied mathematics; and 1.6 percent in "other." However, it must be remembered that many of the students who take the liberal arts or general curriculum qualify for teaching by virtue of taking the required courses in professional education that are necessary for certification. For this reason it seems reasonable to estimate that about half of those who get degrees in mathematics are qualified to teach mathematics in secondary schools.

Undergraduate program characteristics

Another major portion of the survey dealt with various characteristics of undergraduate mathematics programs. Following are some of the highlights (data based upon the responses of all 877 institutions except as noted):

a) 75 percent required an admissions examination of some sort which required mathematics as part of it. Technological institutions (91 percent of them) required such examinations more frequently than did other types of institutions. Also, private institutions (79 percent) required such examinations more often than did the public institutions (66 percent). The CEEB aptitude test was the most common examination (57 percent of the institutions).

b) 59 percent administered a placement examination. Of these institutions, about 61 percent reported that they used standardized or nationally distributed examinations. The subject most commonly tested for was algebra (88 percent), and the most common reason given for administering the test was to determine the specific course for the student to enroll in (70 percent).

c) 67 percent had programs of advanced standing. Of these, 53 percent said that they gave college credit toward graduation for courses skipped. Many of the institutions (48 percent) that grant advanced standing said that they did so on the basis of a proficiency examination made and constructed locally; 37 percent, in accordance with scores made on a proficiency examination of a national agency; and 15 percent, by some other measures.

d) 59 percent offer mathematics courses which they regard as prerequisite or remedial. Intermediate algebra was the most commonly offered course, followed by elementary algebra. Fifty institutions gave trigonometry and 35 institutions gave college algebra as prerequisite instruction. Eighty-four institutions re-

ported that they had at one time offered prerequisite instruction but had discontinued it during the past ten years. The reasons for discontinuing such instruction included: students coming to college were better prepared, and, therefore, the need for such instruction was reduced; the belief that such instruction more properly belongs in the high school or an extension activity; the shortage of faculty and the priority of existing faculty necessitated limiting service to the regular program of instruction.

e) 16 percent require an undergraduate thesis of some or all the mathematics majors. Of those institutions with this requirement, 55 percent required a thesis of honor students only; 40 percent, of all mathematics majors; and 5 percent, of other types of students.

f) 33 percent required that all students, prior to their graduation, take at least one mathematics course of college level; 44 percent of the public institutions had such a requirement compared to 28 percent of the private institutions. This requirement existed in 22 percent of the universities, 29 percent of the liberal arts colleges, 52 percent of the teachers colleges, and 78 percent of the technological institutions.

g) 30 percent offered a special program, such as an honors program, for the superior undergraduate mathematics student. The size of the institution seems to be a very important factor, since 57 percent of the largest institutions (over 5,000 enrollment) offered such a program, whereas only 17 percent of the smallest institutions (under 700 enrollment) did.

h) 426 institutions (49 percent) indicated that they had a mathematics club. Of this number, 62 were affiliated with Pi Mu Epsilon; 52, with Kappa Mu Epsilon; 276 were local; and 47 were "other." Clubs are most likely to be found in the universities (73 percent) and least likely in the liberal arts colleges (42 percent).

i) 49 percent reported that they used classroom techniques other than the standard or traditional lecture-recitation system. Other than "Continental Classroom," independent study was the most commonly used technique, being utilized primarily by relatively small, private, liberal arts colleges. Next most common was the large lecture, with help sessions which were used primarily by large universities. This practice was used only sparingly in the North Atlantic region.

j) Only 17 percent had either a mathematics library or mathematics-science library. Of these, 40 percent had departmental libraries and 60 percent had the combined library. Most of the institutions having such libraries were among the universities, the large institutions (over 5,000 enrollment), and to a slight extent were centered in the North Atlantic region. Only 30 percent of the institutions not having separate libraries wished to have them. These were mostly the larger institutions.

k) In 1961 a total of 163 institutions had a digital electronic computer on campus. Many of the larger institutions had several such installations. A number of other institutions reported that, while they had no digital computer of their own, they had use of an industrial facility nearby or the computer of a neighboring institution. A number of institutions which had no computer expressed a desire for one.

l) Respondents indicated innovations in undergraduate mathematics programs since 1950 as follows: 22 percent had introduced new degree programs; 59 percent had substantially expanded course offerings; 47 percent had introduced freshman courses emphasizing such concepts as structure, logic, set theory, and so on; 24 percent had provided new courses considered appropriate for biological and social science majors; 36 percent had introduced a new program, or

had substantially altered a previous program, for the undergraduate preparation of mathematics teachers; 17 percent had provided courses and instruction leading to careers in data processing and computing; 18 percent had introduced an honors program; 30 percent had introduced a program of advanced standing.

Master's programs in mathematics

Part II of the questionnaire was devoted to master's and doctoral programs. The master's section was divided into master's programs in mathematics and master's programs specially designed for the teaching of mathematics. The coverage in each of the two master's types of programs is believed to be better than 95 percent and in the doctoral programs, 100 percent.

Data were obtained on 220 master's programs in mathematics. Except in a very few instances (for example, the separate master's programs in the College of Letters, Science, and Arts and in the Institute of Technology at the University of Minnesota), these programs represented different institutions or distinct campuses of institutions, such as the University of California campuses.

The Master of Arts (M.A.) degree was the sole degree awarded in 41 percent of the programs; the Master of Science (M.S.), the sole degree in 30 percent of them; and either the M.A. or M.S. in 28 percent of them. Three institutions reported that they conferred an A.M. degree and two, an S.M. degree.

Fifty-nine percent of the programs had either 30 semester credit hours or 45 quarter hours as a specific total credit-hour requirement for the degree (including credits for thesis if they were part of the requirement). With very few exceptions, the credit-hour requirement was all, or nearly all, in mathematics.

A thesis was required in 52 percent of the programs and optional in 35 percent of them. Twenty-eight institutions made

no provision at all for the writing of a thesis. A modern foreign language was a requirement in 36 percent of the programs. The Johns Hopkins University and Bryn Mawr College required two modern foreign languages for the master's degree in mathematics. French, German, or Russian were frequently mentioned as being desirable languages in meeting the language requirement.

It was possible to earn the master's degree in mathematics through evening and/or Saturday study alone in 27 percent of these master's programs and through summer study alone in 37 percent of them.

Princeton University was the only university with a doctoral program in mathematics which did not report the existence of a master's program in mathematics. California Institute of Technology reported that, although a master's program in mathematics existed, such a degree was very exceptional.

Master's programs specially designed for the teaching of mathematics

Master's programs specially designed for the teaching of mathematics were offered at 183 institutions and branches of institutions. These programs were primarily directed at upgrading the qualifications of secondary school teachers.

Because of the emphasis in recent years on improved teacher preparation, especially with the introduction of newer mathematical concepts in many of the curricula in the schools, many of these programs had been newly established. A new degree, Master of Arts in Teaching (M.A.T.) was offered at 28 institutions. Generally the emphasis in such programs has been on mathematics content, although often the courses are specially designed for secondary teachers and are not creditable toward a master's or doctor's degree in mathematics.

There was great variation in the names of degrees awarded in these programs.

Besides the M.A.T., other commonly used designations included Master of Arts (M.A.), Master of Science (M.S.), Master of Arts in Education (M.A. in Ed.), Master of Science in Education (M.S. in Ed.), Master of Education (M.Ed.), and M.S.T. (Master of Science Teaching).

About half of these programs (49 percent) required either 30 semester credit hours or 45 quarter credit hours. The lowest figure in any program was 24 semester credit hours, and the highest, 60 quarter credit hours (figuring two semester credit hours as being equivalent to three quarter credit hours). There was considerable variation from program to program in the distribution of credit requirements in mathematics and in education courses.

In 21 percent of the programs a thesis was required, and in 40 percent, it was optional. A modern foreign language was required in 9 percent of the programs.

It was possible to obtain one of these degrees at 74 percent of the institutions through summer study alone and at 30 percent through evening and/or Saturday study alone. The fact that almost three-fourths of the colleges and universities made it possible to earn a degree through summer study alone was evidence of the special effort made to accommodate teachers.

In-service institutes

One of the questionnaire items was concerned with programs of in-service education of mathematics teachers. Respondents were asked to report on in-service programs of at least two weeks' duration held during the summer of 1960 and the academic year of 1959-60. Information on National Science Foundation institutes was not solicited since this information could be obtained from the Foundation itself.

The data from the National Science

Foundation showed that during the academic year of 1959-60 and the summer of 1960, a total of 365 institutes of various kinds (summer, academic year, and in-service) and conferences, including only or partially mathematics, were attended by 11,875 mathematics teachers. Of the 877 institutions participating in the survey of the Office of Education, 178 institutions, or 20 percent, reported having held institutes other than those of the National Science Foundation. About three quarters of these institutes were supported by the institutions themselves, with 12 percent of them receiving support from private corporations or foundations. The numbers of teachers attending these institutes were not asked for, and consequently comparison with the National Science Foundation institutes cannot be made in this regard.

Doctoral programs in mathematics

The growth of doctoral programs in recent years is impressive. During the decade of the 1950's, 75 institutions (counting as separate institutions the University of California at Berkeley, the University of California at Los Angeles, the University of North Carolina at Chapel Hill, and the North Carolina State College at Raleigh) awarded at least one doctoral degree in mathematics. By the middle of 1961, 94 such institutions were offering doctoral programs in mathematics, including such specializations as applied mathematics and statistics, which are separate departments in some universities. Several of the respondents in this survey indicated that plans were under way to inaugurate doctoral programs at their institutions.

Forty of the 94 institutions (about 43 percent) had no specified minimum credit or course unit requirements for the degree. Several of the respondents emphasized that the figures they gave represented the absolute minimum re-

quirements and that generally the totals for typical students were higher. Others mentioned that, irrespective of specified requirements, the conferral of a doctorate degree depended not so much upon the accumulation of credits but upon the demonstration on the part of the candidate of qualifications considered by his faculty as being requisite for the doctorate degree and upon the writing of a thesis involving original results. Some respondents stated simply that their minimum specified requirement was three years of study beyond the baccalaureate.

The minimum credit requirements at the 52 institutions which specify them varied considerably from institution to institution. Two institutions specified the number of courses required instead of the number of credits. As in master's degree programs, there were variations even within institutions which had two or more departments. Credits for thesis were included in the specified minimum requirements at 30 of the 52 institutions having credit requirements; at the 22 other institutions, credits for thesis were in addition to the specified minimum credit requirements.

The Doctor of Philosophy (Ph.D.) degree was the sole degree awarded at 93 institutions. The Massachusetts Institute of Technology offered both the Ph.D. and the Doctor of Science (Sc.D.) degrees. Reading comprehension in two modern foreign languages was required in all programs with the exception of two programs at Harvard University (statistics and applied mathematics, which required only one language). In addition to the major thesis required in all doctoral programs, Harvard University also required the writing of a minor thesis on a topic not related to the major thesis, with a time limit of several weeks. Rice University had a similar requirement but discontinued it in 1959-60.

Doctoral programs specially designed for the teaching of mathematics

In 1961, 23 institutions offered doctoral programs specially designed for the teaching of mathematics. Four of these programs had been only recently established.

During the three-year period covered by this study, 63 doctorates in the teaching of mathematics were awarded, making the total program throughout the United States considerably smaller than the program in straight mathematics, with 864 degrees. Nevertheless, because of the growing interest in the teaching of mathematics at all levels, these programs are significant.

The objectives of these programs vary. The objective at Yeshiva University is to prepare college teachers of mathematics. An expository or analytical thesis and nine credits in education and psychology are the only essential differences from the traditional doctorate in mathematics. In most other programs the objective is to prepare an individual with dual competencies in mathematics and in professional education. Such degree holders frequently become senior college or junior college teachers of mathematics, professors of mathematics education in universities, and specialists in mathematics education at local, state, and national levels.

The Doctor of Philosophy (Ph.D.) degree was the only degree offered at eight of the 23 institutions; the Doctor of Education (Ed.D.) degree the only degree in six others; and either the Ph.D. or the Ed.D. in the other 11. The credit requirements in mathematics and in professional education varied from institution to institution.

In some instances the requirements in mathematics exceeded those in professional education, and in others the reverse was true. The modern foreign language requirements also varied. Nine institutions required two languages. Three

institutions had no foreign language requirement, and another required it only if it were considered needed for the thesis. At the institutions where the language requirements varied with the kind of degree, the Ph.D. degree requirements in languages were higher than those for the Ed.D. At several institutions, proficiency in another competency, such as statistics or the ability to use a computer, could be substituted for the foreign language requirement. In addition to the major thesis, Pennsylvania State University required the writing of a minor thesis.

Teachers College of Columbia University, with 18, was the leading producer of these doctorates during the period January 1958 to January 1961, and New York University was second with 15; Ohio State University and the University of Texas were tied for third at five.

In recent years there has been an increasing number of colleges and universities offering programs designed to produce college teachers with greater teaching skill and, also, better general understanding of higher education. For this reason the following question was included in the questionnaire: "Does your institution offer courses or seminars in college teaching or other aspects of higher education?"

A total of 64 departments in 63 different institutions reported in the affirmative; 13 said that such courses or seminars were required; 21, that they were not required but encouraged; and 25, that they were neither required nor particularly encouraged. (There are, however, more than 63 institutions having such programs because in a number of institutions department heads either did not report on them or were unaware of their exist-

ence.) The types of programs varied from a single course or supervised teaching to a minor in higher education at one institution.

Federal support

As part of the effort to strengthen the scientific base of our country, the Federal Government is supporting a number of programs at each level of education. Under title III of the National Defense Education Act of 1958, Federal grants to states on a matching basis for the acquisition of mathematics equipment and minor remodeling in primary and secondary schools amounted to \$9,359,948 for the three fiscal years 1959-61. Due to NDEA support, the number of persons designated as state supervisors or consultants in mathematics rose from nine people prior to September 1958, to 75 at the present time.

At the higher education level, students who show aptitude for mathematics are among those given preference for loans under the NDEA loan program. As well as institutes for mathematics teachers at all levels, the National Science Foundation has programs for high-ability undergraduate students, equipment grants, and fellowships for graduate mathematics students and mathematics faculty. During four years, a total of 40 mathematics programs have been approved and 290 fellows in mathematics have been supported under the graduate fellowship program of NDEA.

Since the field of mathematics is growing so rapidly, it is gratifying to observe the interest that is being shown both in curriculum development and financial assistance. Without question this will have a very salutary effect on the advancement of mathematics and the strengthening of our scientific foundations.